PREDICTING SEDIMENT DELIVERY AND STRATIGRAPHY ON MARGINAL SLOPES AND SHELF BASINS

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Long-Term Goals:

Continental slopes are dynamic features evolving in response to sediment delivery and sediment redistribution by gravitational and other forces. A crucial element to understanding slope stratigraphic sequences, in time and space, is the delineation of stratal geometries, lateral and vertical variability, and three-dimensional geometry of the discrete depositional units. A numerical approach to this problem has the advantage of allowing for the study of a wider range of conditions than can be observed easily in the field, or scaled within a laboratory. Therefore the long-term goals of this project are to develop or improve upon existing numerical models useful for the simulation of sediment delivery and accumulation on continental margins over time scales of tens to thousands of years. Model predictions will help us understand the evolution of slope structure and sediment character on continental margins as a function of sea level, terrestrial sediment delivery, and other relevant factors. ONR interests include the development of a numerical predictor of the acoustic signature of slope margins based on a region's geological history.

Scientific Objectives:

1. Develop a model to simulate sediment delivery (fluvial input) to continental margins — including the influence of seasonal effects of river flooding, climate trends, random catastrophic events, and the effects of fluctuating sea-levels on sediment input.
2. Test/calibrate the 'sediment delivery model' with observations made on the Eel and Klamath Rivers in northern California, rivers that have large sediment inputs and conduits across the shelf that may act as shelf-slope transport pathways from these point-source origins.
3. Develop a 'multi-process sedimentation model' to help understand how external forcing mechanisms affect the events that control the slope morphology and stratigraphy, including:
• simulations of fluvial delivery of sediment onto the continental margins;
• simulations of individual mass movements, including submarine failure and debris flow or turbidity current runout;
4. Using results from the multi-process sedimentation model, simulate the seismo-acoustic features of continental margins at a scale directly comparable with very-high resolution (e.g. Chirp and Huntec) seismic records and geotechnical properties observed on cores (i.e. at the scale of individual beds).

Background:

Previous process-response models have been limited in their ability to deal with the natural variability of a river's discharge, thus weakening their ability to provide realistic simulations of offshore sedimentary deposits: typically they have used a steady-state constant-flux approach. Furthermore, previous models used to simulate the formation of continental margin stratigraphy had limited or no ability to accurately predict the properties (e.g. grain size, bulk density) of margin deposits. Often that was because either: 1) the various processes known to move sediment onto the continental margins were highly parametized in the modeling schemes; or 2) the sediment transport algorithms were so sophisticated and singular in approach that their use in making predictions in the hundred to thousand year range was impractical. Our study addresses these limitations by utilizing semi-independent basin-scale models to simulate a river discharge delivering a multi-sized sediment load onto and across a continental margin using a variety of sophistication in understanding bedload dumping at the river mouth, transport and deposition of turbidity currents generated near a delta front, sedimentation under buoyant river plumes, current and

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From: Director, Office of Naval Research, Seattle Regional Office, 1107 NE 45th St., Suite 350, Seattle, WA 98105

To: Defense Technical Center, Attn: P. Mawby, 8725 John J. Kingman Rd., Suite 0944, Ft. Belvoir, VA 22060-6218

Subj: RETURNED GRANTEE/CONTRACTOR TECHNICAL REPORTS

1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.

2. Please contact me if you require additional information. My e-mail is *silverr@onr.navy.mil* and my phone is (206) 625-3196.

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wave erosion and transport, and debris flows generated from slope instabilities.

Approach:

• Improve existing climate-driven drainage basin simulator (RIVER3: Syvitski and Alcott, 1995) to accept input from meteorological station data (MSD) or output from a Global Circulation Model (GCM) and to predict realistic return periods of river flooding, and handle longer-term climate trends.
• Acquire Eel & Klamuth River (California) drainage-basin climate data from NOAA, and river discharge and sediment load data from USGS, and test new (RIVER4) version of model.
• Develop a world-wide data set on river floods and loads, including drainage basin properties, to help predict the return interval of turbidity currents generated at river mouths via (hyperpycnal inflows).
• Develop a numerical model to simulate the run-out distance, the shape and properties of deposits laid down by these sediment laden river floods — test model with observations of the 1663 Saguenay River event
• Develop an approach to calculate the sediment loads on a daily basis from gauged and ungauged rivers.
• Determine how sea level fluctuations can affect the sediment loads of rivers based on a geomorphic-climatic framework.
• Develop a 2-D buoyant 'plume' model wherein a river's sediment load is advected by the river-induced velocity field and diffused by turbulence.
• Incorporate this PLUME model into an established multi-process sedimentation model (DELTA: Syvitski and Alcott, 1995) and accept daily input conditions of a rivers' discharge as determined from the improved RIVER model
• Develop 2-D models to predict the run-out distance, the shape and properties of surge turbidity currents including the transition from debris flows — test model with observations of the 1979 Nice (Var River) event.
• Develop a numerical scheme (FACIES) to track the properties of sediment deposits affected by these transport pathways and predict lithologies of offshore sediment core sites
• Based on the predicted acoustic properties of these deposits, generate synthetic seismic profiles from given high-resolution source signatures (CYNTHIA), including effects of sound attenuation through the sediment layers.

Accomplishments and Results:

• RIVER now accepts direct input from MSD or output from a GCM (monthly averages and standard deviations of temperature, precipitation and evaporation and their interannual variations). When applied to the Eel River drainage basin, River4.1 successfully captures the range in magnitude and return interval of peak discharge events and sediment loads. There appears to be little relation between high precipitation years and river flood years, a diagnostic observation captured by RIVER4.1.
• The largest single data set (279) of rivers including average and flood discharges and their sediment loads was developed; it covers 75% of the landmass that drains into the world oceans. Southeast Asian rivers have sediment loads so high that nine rivers experience underflows at their mouths for at least one episode per year. Elsewhere, small and medium size rivers trigger underflows at their mouths with longer return intervals (10 to 1000 yr). Large rivers are unable to ever generate hyperpycnal underflows. Developed equations and nomagrams may assist engineers in their assessment of continental margins offshore of gauged and ungauged river basins.
• INFLOW was developed to numerically simulate hyperpycnal flow dynamics at river mouths. The model can provide run-out distance, shape and lithology of deposits. Simulations compare well with seismic and core observations that characterize seafloor deposits resulting from the 1663 Saguenay River flood.
• For the first time, a method is developed that allows rating coefficients for gauged and ungauged rivers to be predicted: sediment loads of rivers on a daily basis can be estimated to within 30% of their measured values, although prediction/observation comparisons are made over a 3 to 5 order-of-magnitude range, and over a wide range of hinterland conditions.
• Using empirical relationships between hydrometric, morphometric and climatic data for 279 rivers, sea-level fluctuations are shown to influence river discharge and sediment loads, and frequency of underflows generated at river mouths: e.g. during sea level lowering, turbidity current activity decreases where rivers merge and giant rivers form; in contrast, hyperpycnal activity may increase for smaller rivers, particularly in tectonically active areas.
• A Navier-Stokes approach was used to complete a 2-D buoyant PLUME model, that solves the plume generated from a river's discharge as a non-dimensioned inventory of a 2-D (x,y) grid: sedimentation is governed by a first-order removal rate scheme for each grain size. PLUME predictions were verified against field observations on river plumes

in Alaska, British Columbia and Norway.

• RIVER was linked to PLUME which together allow the multi-process sedimentation model DELTA to simulate sediment accumulation rates on continental margins on a daily basis and for time periods 1 to 10,000 yr or longer. The influence of flood deposits on shaping the development of continental margins and influencing mass sediment failures can now be properly examined.

• Psuedo 2-D SURGE model was developed to analyze the rheological transition of a debris flow (visco-plastic scheme) to a turbidity current (Newtonian scheme), and includes the influence of seafloor erosion, and bedform and sediment deposition from surge-type currents. The model tested favourably against observations of the 1979 Nice (Var River) submarine slide, including the offshore location of sedimentary structures, erosion features and extensiveness of the sand deposit.

• FACIES now provides a user-friendly graphical interface to use the above numerical models to track the ever-changing properties of offshore deposits affected by a variety of marine processes over long simulation periods. Bin-averaging routines allow the study of data loss at specified spatial resolution schemes.

• CYNTHIA, using a Fast-Fourier Transform scheme, allows for the sediment property predictions of FACIES to be used to produce a synthetic acoustic response from a given seismic-source signature. Simple attenuation schemes allow reasonable seismic profile records to be produced.

Scientific Impact and Transitions Accomplished:

We are beginning to close the research loop of sediment transport studies linked to marine process studies linked to geophysical and sediment core observations, using numerical approaches. This last year >10,000 lines of ANSI standard Fortran and C code were created and added to the evolving suite of SEDFLUX models, each new model addition being tested against known observational data sets. The role of climate on the frequency of river floods, the role of river floods on offshore sediment patterns, and the role of offshore morphology on sediment failure styles and sediment redistribution processes have all been examined in this last year. Many of the modeling schemes remain 2-D and conversion to 3-D approaches remains a future goal.

1994/95 ONR support for STRATAFORM Project

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FY95 Publications

Ross, W. C., Halliwell, B. A., May, J. A., Watts, D. E., and Syvitski, J. P. M. 1994. The Slope Readjustment Model: A New Model for the Development of Submarine Fan/Apron Deposits. Geology: 22: 511-514.

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Graduate students: 2 (Ph.D.) — Kenneth Skene & Mark Moorehead

Undergraduate students: 1 (B.Eng.) — Jane Alcott [Female]

PostDoctoral Fellows: 3— H.J. Lee [Minority-Korean]; Kumiko Azetsu-Scott (Minority & Female] & Thierry Mulder

Conferences & Workshops:

CAPE: Circum-Arctic Paleo Environments, Copenhagen DK, 1995

Conference of the Geological Association of Canada, Victoria, BC, 1995

COLDSEIS: Seismic Facies of Marine Glacigenic Deposits Workshop, Halifax NS, 1995

Service on Committees/panels:

Co-leader of ONR's STRATAFORM's slope program component

Leader/Convenor of International COLDSEIS working group

U.S.A. Representative on Global Change (PAGES) core project CAPE

Chair of Selction Panel for the Huntsman Award for Outstanding Achievements in Oceanography

Scientific Advisory Board for the Institute of Arctic & Alpine Research, University of Colorado

Board of Director of ARCUS, the Arctic Research Consortium of the United States

Director of the Institute of Arctic & Alpine Research and chair of many university committees and panels

Honors & Awards:

Keynote Speaker: Living with Deltas Symposia GAC, Victoria BC, 1995

Keynote Speaker: Seismic Facies of Marine Glacigenic Deposits Workshop, Halifax NS, 1995